PHENIX Measurement of High-p_T Hadron-hadron and Photon-hadron Azimuthal Correlations

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Abstract.

High-p_T hadron-hadron correlations have been measured with the PHENIX experiment in $\mathrm{Cu}+\mathrm{Cu}$ and $\mathrm{p}+\mathrm{p}$ collisions at $\sqrt{s_{NN}} = 200$ GeV. A comparison of the jet widths and yields between the two colliding systems allows us to study the medium effect on jets. We also present a first measurement of direct photon-hadron correlations in $\mathrm{Au}+\mathrm{Au}$ and $\mathrm{p}+\mathrm{p}$ collisions. We find that the near-side yields are consistent with zero in both systems. By comparing the jet yields on the away side, we observe a suggestion of the expected suppression of hadrons associated with photons in $\mathrm{Au}+\mathrm{Au}$ collisions.

1. Introduction

The method of high-p_T two-particle azimuthal correlations is a unique probe of the hot, dense medium created in heavy-ion collisions at RHIC. Early RHIC results on hadron-hadron correlations indicate a strong modification of the away-side jet shape and yield by the medium [1]. These modifications provide valuable constraints on the properties of the hot, dense medium. However, the physics interpretations of the away-side modification are complicated as the trigger hadrons mostly come from the surface of the medium. Direct photons, due to their weak coupling with the medium, provide a cleaner calibration of the energy and direction of the away-side jets. Thus, direct photon-hadron correlations can provide less biased and quantitative measurements of the away-side modifications.

At RHIC energies, identification of direct photons is difficult due to the large number of background photons from hadronic decays, mostly from π^0 decays. Therefore the extraction of the direct photon-hadron per-trigger yields relies on a statistical subtraction of the decay photon-hadron per-trigger yields from the inclusive photon-hadron per-trigger yields.

† For the full list of PHENIX authors and acknowledgements, see Appendix 'Collaborations' of this volume

A two-particle correlation function ($C(\Delta\phi)$) as measured in the PHENIX central spectrometer arms is constructed as

$$CF(\Delta\phi) \sim \frac{dN_{real}/d\Delta\phi}{dN_{mix}/d\Delta\phi} = Jet(\Delta\phi) + Bkdg(\Delta\phi) \quad (1)$$

where $dN_{real}/d\Delta\phi$ is the same-event pair distribution and $dN_{mix}/d\Delta\phi$ is the mixed-event pair distribution. The mixed-event distribution is used to correct for the non-uniform PHENIX pair acceptance. The correlation function (CF) can be decomposed into a jet function $J(\Delta\phi)$ and a underlying flow modulated background term. After subtracting the background, we correct the remaining $J(\Delta\phi)$ by the single particle efficiency and the PHENIX acceptance, then normalize it by the number of triggers, thus obtaining the per-trigger yield [3].

2. High-p_T hadron-hadron correlations

The per-trigger yield distributions are fitted with a double Gaussian function to extract the Gaussian width for both peaks ($\Delta\phi = 0/\pi$ for near-side/away-side). The jet yield is integrated over a $\Delta\pi$ region of π around each peak. Two other useful jet variables are defined as

$$p_{out} = p_{T,asso} \cdot \sin(\Delta\phi), \quad x_E = \frac{p_{T,asso}}{p_{T,trig}} \cdot \cos(\Delta\phi) \quad (2)$$

p_{out} is the transverse momentum component of the associated particle perpendicular to the trigger, x_E measures the relative associated particle p_T to trigger p_T along the trigger direction.

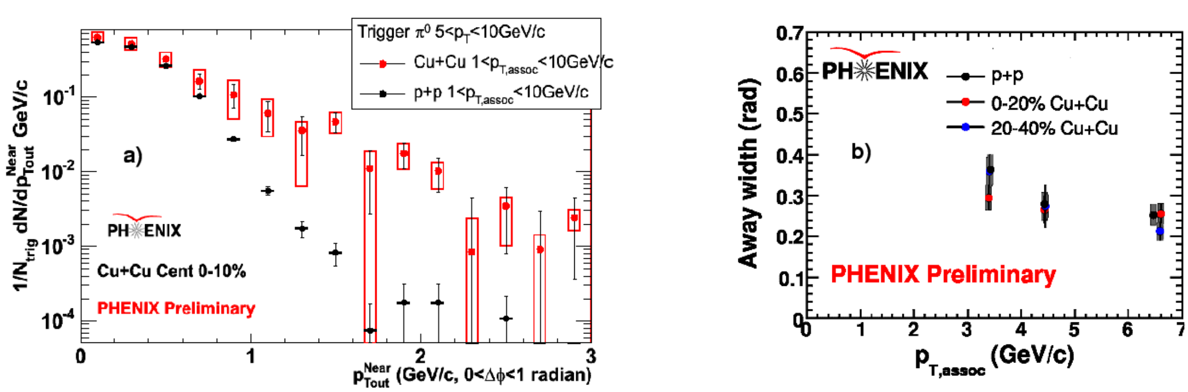

Figure 1. (a) Near-side p_{out} distribution, p + p (black) and Cu + Cu (red) and (b) Away side Gaussian width as a function of associated p_T, p + p (black), Cu + Cu 0 − 20% (red) and Cu + Cu 20 − 40% (blue)

Fig. 1(a) shows the near-side p_{out} distribution. Near-side Gaussian widths are also extracted and no significant difference is seen between Cu + Cu and p + p. However, the p_{out} distribution is a more sensitive quantity to study medium-induced jet modification, especially at the large p_{out} region. On Fig. 1(a), we see an enhancement in Cu + Cu compared with p + p in the tail region. It indicates that the near-side jets are modified

by the medium through additional radiation with components transverse to the jet direction. Fig. 1(b) shows the away-side Gaussian widths, we do not see a width broadening from $\mathrm{p+p}$ to $\mathrm{Cu+Cu}$. We are working on the away-side p_{out} distribution to better study the away-side shape modification.

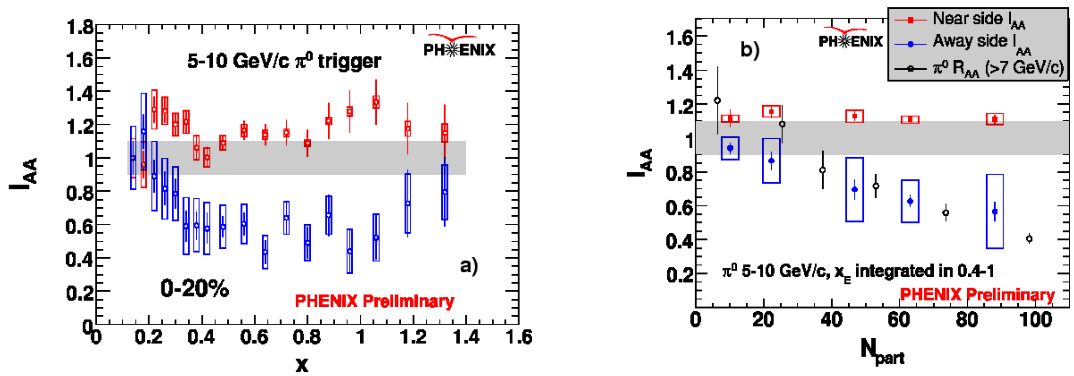

Figure 2. (a) I_{AA} as a function of associated p_T, near side (red) and away side (blue). and (b) Integrated I_{AA} and R_{AA} as a function of N_{part}, near side (red), away side (blue) and R_{AA} (black).

PHENIX measures jet yield modification via I_{AA}, which is the yield ratio of $\mathrm{Cu+Cu}$ to $\mathrm{p+p}$. $I_{AA} = 1$ indicates no suppression in $\mathrm{Cu+Cu}$ with respect to $\mathrm{p+p}$ whereas the lower the I_{AA}, the stronger the suppression. Fig. 2(a) shows I_{AA} of most central (0-20%) $\mathrm{Cu+Cu}$ collisions. The near-side I_{AA} is close to unity and the away-side I_{AA} shows substantial suppression in the central $\mathrm{Cu+Cu}$ collisions. Fig. 2(b) shows the I_{AA} integrated over $x_E = 0.4 - 1$ as a function of N_{part}. The near-side I_{AA} is consistent with unity within error bars, whereas the away-side I_{AA} shows a decreasing trend from peripheral to central collisions. On the same plot is a comparison to the nuclear modification factor R_{AA} of high-p_T π^0s, the observed I_{AA} is similar to the nuclear modification factor.

3. High-p_T direct photon-hadron correlations

While dijet measurements suffer from trigger bias and possible trigger surface bias, an ideal probe for studying the jet modification in medium is the use of direct photon-hadron correlations [4]. This measurement is aided by the fact that PHENIX has observed a factor of $\sim$2 excess of photons above the hadronic decay background at $p_T > 5GeV/c$ in the most central $\mathrm{Au+Au}$ collisions, which is consistent with direct photon production as calculated by pQCD [5]. We employ a statistical subtraction method to extract direct photon-hadron correlations and per-trigger yields. First, the inclusive photon-hadron per-trigger yields (Y_{incl-h}) are constructed by subtracting the background term (using the measured inclusive photon v_2) from the inclusive photon-hadron CF. Then, starting from π^0-hadron pairs, we construct the decay photon-hadron CF. This is done by performing a pair by pair weighted sum to convolute the

contributions from feeddown from π^0 decays. The weights applied are derived from the π^0 decay kinematics. From the decay photon-hadron CF, we subtract the background term using the decay photon-hadron v_2 derived from the measured π^0 v_2 in order to finally get the decay photon-hadron per-trigger yields. The inclusive photon and π^0 v_2's that we used were measured with the standard PHENIX single particle method [2]. Once both per-trigger yields are obtained, the direct photon-hadron per-trigger yield (Y_{dir-h}) is found by:

$$Y_{dir-h} = \frac{1}{R-1}(R \cdot Y_{incl-h} - Y_{decay-h}) \tag{3}$$

in which R measures the number of inclusive photons divided by the number of decay photons from all decay channels. R is independently measured by PHENIX [5].

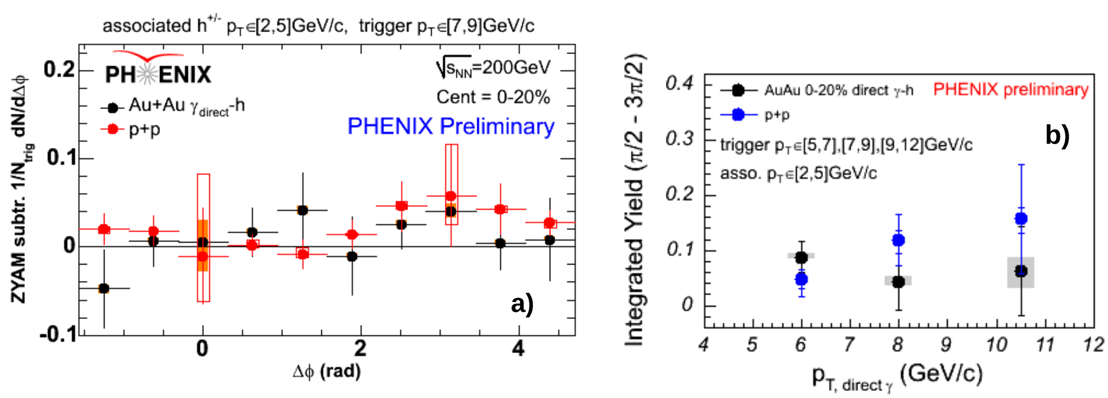

Figure 3. (a) The direct photon-hadron per-trigger yield in $\mathrm{p+p}$ (red) and $\mathrm{Au+Au}$ (black) and (b) The integrated away side yields as a function of trigger photon p_T in $\mathrm{p+p}$ (blue) and $\mathrm{Au+Au}$ (black).

The direct photon-hadron yield in $\mathrm{p+p}$ is an important baseline measurement. Fig. 3(a) shows direct photon-hadron per-trigger yield in $\mathrm{p+p}$, a near-side yield consistent with zero is seen, which is consistent with what one would expect from direct photon and small fragmentation photon contribution. A comparison between the $\mathrm{p+p}$ per-trigger yield and the PYTHIA simulation results shows a qualitative agreement. In $\mathrm{Au+Au}$ collisions, the direct photon-hadron per-trigger yield is shown in Fig. 3(a). The near-side yield is consistent with zero and the away-side yield is small.

Comparing $\mathrm{p+p}$ to $\mathrm{Au+Au}$ in Fig. 3(a), we see some indication of away-side suppression. Although error bars are large, there is a systematic trend that the $\mathrm{p+p}$ yield is higher than $\mathrm{Au+Au}$. To make a quantitative statement, the away-side yield is integrated over the $[\pi/2, 3\pi/2]$ region. Fig. 3(b) shows the integrated away-side yields as a function of trigger photon p_T. We observe an increasing trend of yields in $\mathrm{p+p}$, whereas yields in $\mathrm{Au+Au}$ are suppressed, especially when $p_T > 7GeV/c$.

4. Conclusions

PHENIX has made precision measurements of high-p_T dijets. We observe near-side jet modification at large p_{out}. Away-side yield is suppressed, whereas the width is unchanged. Also, the away-side I_{AA} is quantitatively consistent with R_{AA}. Moreover, PHENIX has made the first measurement of high-p_T direct photon-hadron yields. The near-side yield is consistent with zero and the away-side yield is suppressed compared to yields in $\mathrm{p+p}$. Therefore these data indicate the modification of the away-side jets from photon triggers in $\mathrm{Au+Au}$.

References

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